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ABSTRACT

This report addresses the critical importance of measuring and evaluating information systems functioning within computer network environments. The focus is on the significant benefits associated with using automated monitoring as the primary information system measurement mechanism within such computing architectures. The large scale, network-based, state-of-the-art OCLC online system is utilized as the information system environment in support of these research and development activities. Within this environment an overall structure for a generalized, automated monitor design is proposed. Monitoring specifications are illustrated at the network supervisor level, the applications processor level, and the database processor level within the OCLC system network architecture. The monitoring concepts, techniques, and parameters presented within this report represent a strong foundation for information system measurement, analysis, and evaluation. When combined with complementary measurement facilities such as controlled benchmarks and synthetic programs, simulation models and controlled user interface experiments, a total comprehensive methodology for information system evaluation can be realized. The principles of automated monitoring have proven their extensibility and generalizability across numerous types of information systems. It is concluded that automated monitoring should be viewed as an essential self-measurement capability within all future information system designs. (Author/RAA)

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Research Report

on

An Overview of a Proposed Monitoring Facility for the Large-scale, Network-based OCLC On-line System

by

Wayne D. Dominick
W. David Penniman
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OCLC, Inc.

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ABSTRACT

This report addresses the critical importance of measuring and evaluating information systems functioning within computer network environments. The focus is on the significant benefits associated with using automated monitoring as the primary information system measurement mechanism within such computing architectures.

The large-scale, network-based, state-of-the-art OCLC On-line System is utilized as the information system environment in support of these research and development activities. Within the environment of the OCLC On-line System, an overall structure for a generalized, automated monitor design is proposed. Monitoring specifications are illustrated at the network supervisor level, the applications processor level, and the data base processor level within the OCLC system network architecture.

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NOTE ABOUT THE AUTHORS

Dr. Wayne D. Dominick is vice-president of Information Management, Inc., a computer science/information systems consulting corporation based in Lafayette, Louisiana. In this capacity, he has served as a consultant to the Research Department at OCLC since 1978. Dr. Dominick received his Bachelor of Science degree in Mathematics from the Illinois Institute of Technology, Chicago, Illinois, and his Master of Science and Doctor of Philosophy degrees in Computer Science from Northwestern University, Evanston, Illinois. Dr. Dominick is also an Associate Professor in the Computer Science Department at the University of Southwestern Louisiana, Lafayette, Louisiana, and serves as an information systems consultant to numerous governmental, industrial, and academic organizations.

Dr. W. David Penniman is Manager of the Research Department at OCLC, Inc., a computerized library network for academic, public, federal, and special libraries. He is currently serving as Acting Division Director of the Development Division and will return to his research activities in mid-1980. Dr. Penniman received his Bachelor of Science degree in Engineering and his Master of Science degree in Journalism/Communication from the University of Illinois, Urbana, Illinois, and his Doctor of Philosophy degree in Communication from The Ohio State University. Dr. Penniman specializes in human/computer interaction research and currently directs a project in that area in addition to his temporary assignment.

Dr. James E. Rush was recently appointed Director of Research and Coordinator of the newly established Office of Planning and Research at OCLC, Inc. From 1973 to 1979, Dr. Rush was Director of the OCLC Research and Development Division. He received his Bachelor of Science degree in Chemistry and Mathematics from Central Missouri State College, Warrensburg, Missouri, and his Doctor of Philosophy degree in Chemistry from the University of Missouri, Columbia, Missouri. Dr. Rush is an Adjunct Associate Professor in the Department of Computer and Information Science at The Ohio State University as well as Adjunct Professor of Library Science at the University of Illinois. He currently is involved in several on-going research and development projects at OCLC.

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I. INTRODUCTION

The processes of measurement and evaluation are critical within any large-scale, computer-based information system. Measures of the efficiency and effectiveness of the current hardware/software technology are essential not only to manage the current system but also to plan and schedule future enhancements to the system.

In addition to measuring and evaluating the efficiency of the technology, the usability of that technology also must be analyzed and evaluated. If a system is to survive and prosper, that system must remain continually responsive to the varying needs of its user community.

This chapter introduces the topics of information system measurement and evaluation. It places primary emphasis on the significant potential for automated monitoring as a powerful measurement mechanism for large-scale, network-based information systems.

A. Measurement and Evaluation of Information Systems

Within recent years, a substantial amount of research has been directed toward the measurement and evaluation of information systems. Some of the major objectives of these activities have included:

(1) Detailed comparative evaluations of different data base organizations. [1, 2, 3, 4, 5]

(2) Analyses directed toward determining overall information system execution efficiency and toward isolating system processing bottlenecks. [6, 7, 8]

(3) Information system models and simulations to project information system performance. [9, 10, 11]

(4) Analyses to determine system and data base usage patterns and/or usage trends. [12, 13, 14, 15]

(5) Analyses of user errors and evaluations of user success and user satisfaction. [16, 17]

An information system is not an autonomous entity, but rather one component within a total human, computing, and organizational environment. Therefore, a methodology for evaluating information systems should not be restricted only to the internal execution efficiency of that system. Evaluations also should be considered between the information system and its supportive environment (operating system, storage devices, computer architecture), and supported environment (data bases, user communities, organizational objectives).

Although each component of an information system evaluation methodology has been addressed successfully within single-processor, centralized computing environments, the measurement problems become substantially compounded within multiple-processor, potentially distributed, computer network environments.

B. Additional Complexities of Network-Based Systems

Within information systems implemented in computer network environments, the additional complexities associated with measurement and evaluation processes manifest themselves in a number of areas:

(1) Interface and intercommunication among multiple, potentially heterogeneous processors. [18]

(2) Support for locally or geographically distributed data bases across storage nodes within the network. [19, 20]

(3) Support for locally or geographically distributed data base management functions across processing nodes within the network. [21]

(4) Use of a communications network to front-end the computer network. [22, 23]

(5) Problems of optimal resource allocation and file allocation across network nodes. [24, 25]

In addition to these complexities, network-based information systems tend to support large user communities (several thousand users) requiring fast (several second response time) concurrent access to large (several million record) data bases. Such system environments absolutely demand the ultimate in state-of-the-art measurement and evaluation facilities.

C. Automated Monitoring as a Measurement Mechanism for Network-Based Information Systems

Automated monitoring is predicated on instrumenting and/or augmenting the information system with automated mechanisms for collecting the data needed to evaluate the system and to evaluate the interfaces to its supportive and supported computing environment. [26, 27] Implemented in hardware, software, and/or firmware, monitors can provide the framework for collecting an entire spectrum of data--from simple counts of events through detailed, context-sensitive, user/system interaction profiles. [28]

Most recent specifications of near-term research needs in the area of information systems place considerable emphasis on the importance of incorporating system self-measurement capabilities into all future computer technology. [29, 30] This is precisely the function of automated monitors.

In the past six years, the authors have been personally associated with the design, implementation, evaluation, and management of automated monitoring facilities for four existing information systems:

(1) RIQS - Remote Information Query System - personalized data base system developed at Northwestern University, Evanston, Illinois. [7, 15, 17, 31, 32]

(2) BASIS - Battelle Automated Search Information System - textual/numeric data base system developed by Battelle Columbus Laboratories, Columbus, Ohio. [12, 13, 14, 33]

(3) MADAM - Multics Approach to Data Access and Management - bibliographic information storage and retrieval system developed at the University of Southwestern Louisiana, Lafayette, Louisana. [3, 4, 16, 34, 35]

(4) MDBM - Multics Data Base Manager - generalized relational and CODASYL-DBTG network data base management system developed by Honeywell Information Systems, with monitor developed at the University of Southwestern Louisiana, Lafayette, Louisiana. [36, 37]

Based on the successes with the use of automated monitoring within non-network-based information systems, the authors felt that monitoring could be employed very effectively within network-based information systems also. The remainder of this report illustrates the use of monitoring within such an environment.

II. OCLC ON-LINE SYSTEM

The OCLC On-line System represents a large-scale, network-based information system developed, maintained, and operated by OCLC, Inc., Columbus, Ohio.

The OCLC On-line System and system network architecture is the environment used to support the research and development activities described in this report. The following two sections give an overview of the capabilities and characteristics of the OCLC environment.

A. Overview of System Capabilities

OCLC is a not-for-profit corporation based in Columbus, Ohio, that provides computer-based service to all kinds of libraries, both large and small. [38, 39] Currently, over 2,000 libraries in 50 states, Puerto Rico, District of Columbia, and Canada are serviced through 20 regional networks. OCLC's major services are provided on-line to library staff and patrons, and a number of important batch-oriented services are provided as well.

On-line service is provided through some 3,000 OCLC terminals installed in OCLC member libraries. These terminals are linked to OCLC's computer system in Columbus, Ohio, via a polled, multi-drop, leased-line, synchronous communication network. [40] Terminals are in communication with the central computer system, although it is unlikely that all transmit data simultaneously. The on-line portion of the OCLC system operates 15 hours a day, Monday through Friday, and 12 hours on Saturday. Response time on the network averages 6.7 seconds during the peak period of the day (9:00 a.m. to 3:00 p.m. EST).*

OCLC users have access to a data base of more than 5,600,000 bibliographic records. Over 55,000,000 location symbols correspond to and identify those libraries in which a given bibliographic item is located. Access to bibliographic data is provided by several search keys, such as author, title, combination of author and title, etc. Records in the data base are available on-line to users during the operational day.

Users of the system not only have search access to the records in the data base, but they also can add records to the data base and, under certain conditions, modify records in the data base. New records are added at a rate of approximately 3,500 per day, which amounts to more than a million new

---

* Response time is the period of time between transmission of a message to the system and receipt of the response, i.e., the total time required to obtain a command from a user's terminal, transmit it to the central site, process it, and return the appropriate response to the user's terminal. The noted average includes all types of user traffic, including input messages with errors.

records a year. All new records are indexed "on the fly" so that they become immediately available to system users.

The OCLC system currently supports cataloging, serials control, and interlibrary loan functions. Acquisitions and union listing functions are scheduled to be added to the system in 1980.

Total system burden is best described in terms of total message traffic from users. On a typical day, users enter over 1,000,000 messages from terminals and in response the system generates a corresponding number of output messages. Input user messages average 27 characters and OCLC output messages average 430 characters. Approximately 60% of the input messages require data base access.

B. The OCLC System Network Architecture

The current (as of 1979 December 1) OCLC On-line System is configured into a system network architecture with processing capabilities at three primary levels [41, 42, 43]:

(1) Network supervisor level, consisting of four Tandem-16 front-end machines performing message transmission, routing, and overall network supervision functions;

(2) Applications processor level, consisting of four large-scale Xerox Sigma 9 machines in a quadruple processor configuration for performing applications-oriented tasks associated with the various OCLC applications subsystems;

(3) Data base processor level, consisting of ten Tandem-16 back-end machines performing all required accesses to the OCLC data bases.

Thus, overall OCLC network architecture is heterogeneous, since different processors are used at different levels within the network. Each specific processing level currently is homogeneous with respect to processor types; however, this homogeneity will not necessarily remain as additional processors, especially at the applications processor level, are added in the future. A diagram of this system network architecture configuration is illustrated in Figure 1.

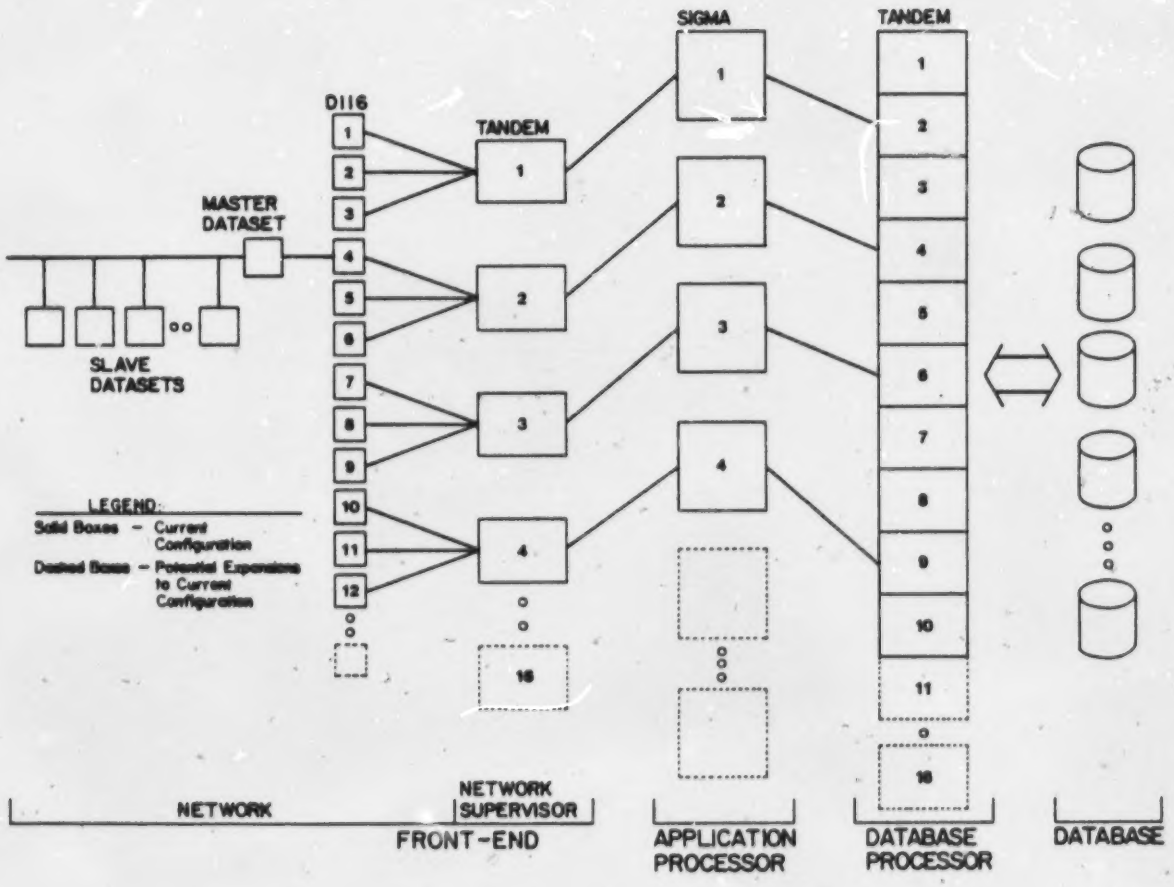

Figure 1. OCLC System Network Architecture

III. A MONITORING FACILITY FOR THE OCLC ON-LINE SYSTEM

A comprehensive monitoring facility for the OCLC On-line System is essential based upon: (1) the scope and magnitude of the OCLC On-line System processing environment; and (2) the critical importance of system execution efficiency and user interaction effectiveness within that environment. This facility will provide the framework for the collection of the information needed to support the continual measurement, analysis, and evaluation of that system.

This chapter defines the primary measurement/evaluation objectives of this research activity, describes the overall structure of the required monitor design, and discusses the salient characteristics of the monitoring facility for each major level within the OCLC system network architecture.

A. Measurement/Evaluation Objectives

The primary objectives of this research effort were:

(1) Creation of a conceptual monitor design capable of supporting multiple evaluation orientations:

  (a) Detailed evaluations of system, subsystem, and network execution efficiency.

  (b) Unobtrusive evaluations of user interaction effectiveness.

(2) Creation of an overall structure for a detailed monitor design capable of supporting multiple views of the OCLC On-line System:

  (a) Application-independent view of the system as a collection of processing levels within a system network architecture.

  (b) Application-dependent view of the system as a collection of applications subsystems.

(3) Design of an application-independent monitoring facility for the system to address the three primary processing levels within the system network architecture:

  (a) Network supervisor level.

  (b) Applications processor level.

  (c) Data base processor level.

(4) Design of an application-dependent monitoring facility for the system to address the primary applications subsystems:

(a) Initial monitoring facilities to support the Cataloging Subsystem [44] and the Interlibrary Loan Subsystem. [45]

(b) Provisions for substantial generality in monitor design to facilitate extensibility for addressing the other OCLC applications subsystems in the future.

(5) Synthesis of the application-independent monitoring facilities and the application-dependent monitoring facilities into a unified monitor design for the entire OCLC On-line System.

(6) Identification of the critical factors and considerations relevant to the design, implementation, evaluation, and use of monitoring facilities within the OCLC environment.

All of the preceding objectives were, in fact, satisfied and the supportive design work is documented in detail. [46] The remainder of this report highlights the salient features of the monitoring facility which was designed to satisfy these objectives.

B. Monitor Design Structure

Within the OCLC system network architecture environment, the design of a monitoring facility to collect information associated with system performance and user interactions must be viewed as a multi-level process.

On one hand, the monitor design is dictated by the structure of the supportive system network architecture. User-initiated transactions travel through the network--operated on by processors at one level and forwarded to the next level for additional processing.

On the other hand, the monitor design is dictated by the applications-oriented tasks associated with the various applications subsystems constituting the total system. From this viewpoint, user-initiated transactions require certain applications processes to be performed, regardless of how a collection of processors may be configured to execute these applications tasks.

These considerations imply that a monitor design must address both network-dependent (application-independent) processing and application-dependent (network-independent) processing.

It is also critical to recognize the desirability of creating a distributed monitor design. In such a design, the monitoring facility would be structured in a distributed manner, with monitor components residing at each level within the network architecture. Each monitor component would collect data associated both with the processing (application-independent and application-dependent) performed at that level and with the routing of the transaction to the next level within the network.

A distributed monitor design also implies a distributed monitor data base design. In such a design, separate monitor files would be created at each network level for storing the data collected at that level. This approach would minimize the data transmission overhead associated with the monitor functions since potentially voluminous and accumulated monitored data for each transaction would not be passed along with the transaction as it travels through the network. Rather, the monitored data would be stored at the network level at which it was originally collected.

This type of a monitor design can be realized by the assignment of a unique identifier (transaction stamp) to each transaction upon its initial entry into the system. Only this transaction stamp would accompany the transaction throughout the network. This would provide the capability for associating the distributed monitored data with the specific transaction for which the data were collected. Thus, a distributed monitor design with a distributed monitor data base design can be realized with a minimum amount of message transmission overhead.

The following sections identify the major activities to be monitored at the different levels within the OCLC system network architecture.

C. Monitoring at the Network Supervisor Level

Monitoring at the network supervisor level addresses three generic categories of activities:

(1) Network availability.

(2) Session initiation and termination.

(3) Transaction processing.

Measurement of network availability includes statistics on network startup, configuration modification during network "up-time", and network shutdown. Specific statistics that will be collected at the network supervisor level to characterize network availability are illustrated in Figure 2.

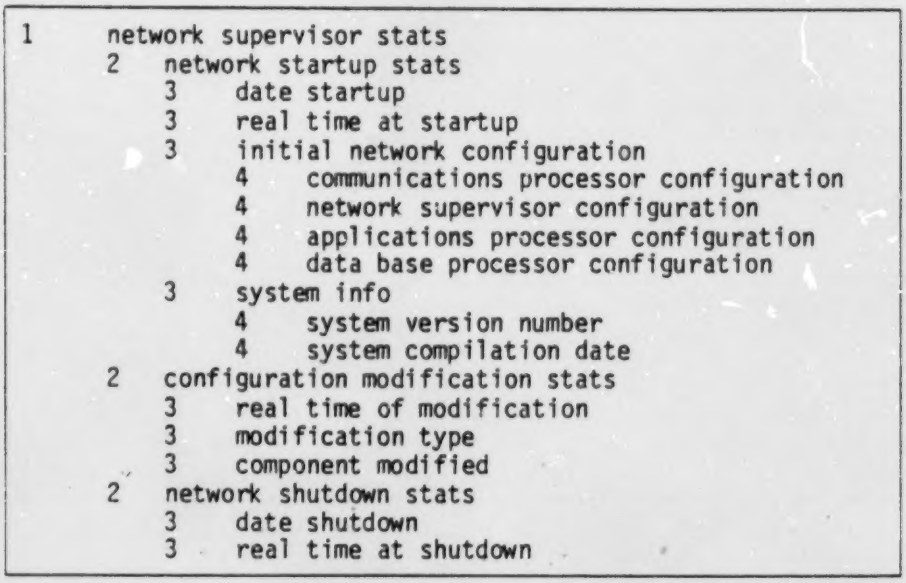

Figure 2. Network Supervisor Statistics: Network Availability

Identification of user session initiation and termination includes statistics on user log-on (session initiation) and user log-off (session termination). Figure 3 illustrates specific statistics that will be collected at the network supervisor level to characterize session initiation and termination.

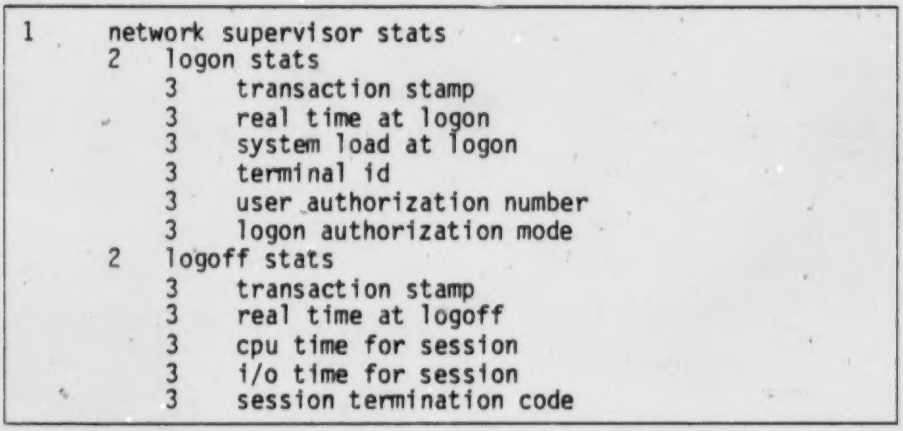
1 network supervisor stats
2 logon stats
3 transaction stamp
3 real time at logon
3 system load at logon
3 terminal id
3 user authorization number
3 logon authorization mode
2 logoff stats
3 transaction stamp
3 real time at logoff
3 cpu time for session
3 i/o time for session
3 session termination code

Figure 3. Network Supervisor Statistics: Session Initiation/Termination

Transaction processing statistics characterize the processing that is performed on user transactions at the network supervisor level. These statistics are illustrated in Figure 4.

The monitoring parameters illustrated within this section provide a quantitative profile of the activities performed at the network supervisor level of the OCLC system network architecture.

```
1     network supervisor stats
      2   transaction stats
          3    transaction stamp
          3    transaction source
          3    send to receive time
          3    real time transaction received
          3    real time transaction forwarded
          3    transaction size
          3    transaction content
          3    application id
          3    cpu time in network supervisor
          3    i/o time in network supervisor
          3    network supervisor machine id
          3    destination machine id
          3    destination queue number
          3    network supervisor termination message number
```

Figure 4. Network Supervisor Statistics: Transactions

D. Monitoring at the Applications Processor Level

Monitoring at the applications processor level, illustrated in Figure 5, addresses statistics which characterize the processing performed at that level on user transactions.

```
1     applications processor stats
      2   transaction stats
          3    transaction stamp
          3    transaction source
          3    real time transaction received
          3    real time transaction forwarded
          3    application id
          3    application function code
          3    request text
          3    system responses and error numbers
          3    system initiated processing
          3    output type
          3    number of entries output
          3    cpu time in applications processor
          3    i/o time in applications processor
          3    applications processor machine id
          3    destination machine id
          3    applications processor termination message number
```

Figure 5. Applications Processor Statistics: Transactions

E. Monitoring at the Data Base Processor Level

Monitoring at the data base processor level addresses two generic categories of measurements:

(1) Data base structurings.

(2) Transaction processing.

Measurements of data base structurings include an identification of the available data bases and statistics characterizing their size and structuring. Specific statistics that will be collected at the data base processor level for each available data base are illustrated in Figure 6.

```
1     data base processor stats
      2   database structure stats
          3    database number
          3    database name
          3    database structure parameters code
          3    size of database
               4    data records file
                    5    number of logical records
                    5    number of physical bytes
               4    index 1 file
                    5    number of logical records
                    5    number of physical bytes
               .
               .
               .
               4    index n file
                    5    number of logical records
                    5    number of physical bytes
```

Figure 6. Data Base Processor Statistics: Data Base Structuring

Transaction processing at the data base processor level focuses on the actual accessing of the available data bases. Figure 7 illustrates statistics characterizing data base accesses. Only data base searching is included; data base maintenance activities are excluded for reasons of brevity.

```
1     data base processor stats
      2   transaction stats
          3     transaction stamp
          3     real time transaction received
          3     real time transaction forwarded
          3     application id
          3     application function code
          3     completion code
          3     cpu time in data base processor
          3     i/o time in data base processor
          3     data base processor machine id
          3     destination machine id
          3     database search stats
                4     database number searched
                4     primary search key
                4     additional search qualifiers
                      5     added qualifier type
                      5     added qualifier
                4     number of entries found
                4     retrieval results
          3     data base processor termination message number
```

Figure 7. Data Base Processor Statistics: Transactions

IV. SUMMARY AND CONCLUSIONS

The monitoring concepts, techniques, and parameters presented within this report and illustrated within the context of the large-scale, network-based OCLC On-line System represent a strong foundation for information system measurement, analysis, and evaluation.

When combined with complementary measurement facilities such as controlled benchmarks and synthetic programs, simulation models, and controlled user interface experiments, all of which are being utilized within the OCLC environment, a total comprehensive methodology for information system evaluation can be realized.

As stated in Chapter I, Section C, the principles of automated monitoring have proven their extensibility and generalizability across numerous types of information systems: personalized data base systems, integrated textual/numeric data systems, bibliographic information storage and retrieval systems, and generalized data base management systems.

Based on these proven successes, the authors conclude that automated monitoring should be viewed as an essential system self-measurement capability within all future information system designs.

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